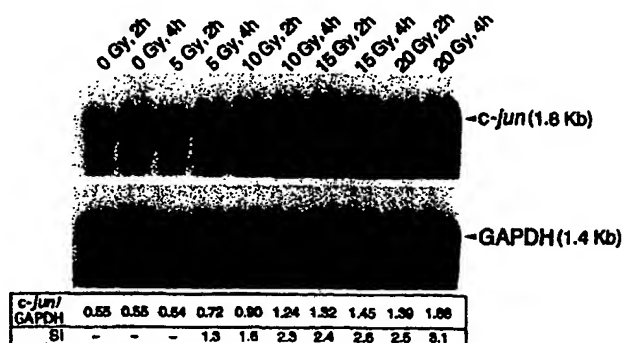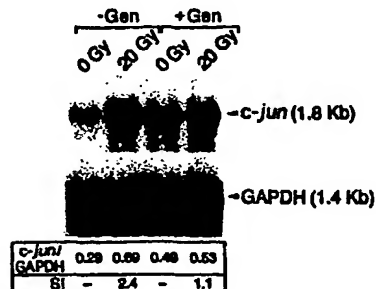## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: METHOD FOR INHIBITING C–JUN EXPRESSION USING JAK–3 INHIBITORS

(57) Abstract

The invention provides the use of a compound that inhibits the activity of Janus family kinase 3 (JAK–3), or pharmaceutically acceptable salt thereof; for the manufacture of a medicament for inhibiting c–jun activation in mammalian or avian cells.

A

B

METHOD FOR INHIBITING C-JUN EXPRESSION
USING JAK-3 INHIBITORS

5

Background of the Invention

The protooncogene *c-jun* is the cellular counterpart of the *v-jun* oncogene of avian sarcoma virus 17. *C-jun* expression is activated in response to a diverse set of DNA-damaging agents including ara-C, UV radiation,

10 topoisomerase II inhibitors, alkylating agents, and ionizing radiation. As an immediate early response gene that is rapidly induced by pleiotropic signals, *c-jun* may have important regulatory functions for cell cycle progression, proliferation, and survival. See Ryder, K., Lau, L. F., and Nathans, D. "A gene activated by growth factors is related to the oncogene v-jun," *Proc Natl Acad Sci*

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for the DNA repair protein O6-methylguanine-DNA methyltransferase (MGMT) and its relationship to cell death, mutation induction and chromosomal instability," *Oncogene. 13:* 1927-35, 1996; Chae, H. P., Jarvis, L. J., and Uckun, F. M. "Role of tyrosine phosphorylation in radiation-induced activation of c-jun
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C-jun encodes the nuclear DNA-binding protein, JUN, that contains a leucine-zipper region involved in homo- and heterodimerization. JUN
10 protein dimerizes with another JUN protein or the product of *c-fos* gene and forms the activating protein-1 (AP-1) transcription factor. JUN-JUN homodimers and JUN-FOS heterodimers preferentially bind to a specific heptameric consensus sequence found in the promoter region of multiple growth regulatory genes. Alterations of *c-jun* protooncogene expression can therefore
15 modulate the transcription of several growth-regulators affecting cell proliferation and differentiation. See Ryder, K., Lau, L. F., and Nathans, D. "A gene activated by growth factors is related to the oncogene v-jun," *Proc Natl Acad Sci USA. 85:* 1487-1491, 1988; Neuberg, M., Adamkiewicz, J., Hunter, J. B., and Mueller, R. "A fos protein containing the Jun leucine zipper forms a
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C-jun plays a pivotal role in Ras-induced transformation and has also been implicated as a regulator of apoptosis when *de novo* protein synthesis
30 is required. *C-jun* induction is required for ceramide-induced apoptosis and stress-induced apoptosis after UV exposure or other forms of DNA damage. This induction is thought to be triggered by activation of JUN-N-terminal kinases (JNKs) (also known as stress-activated protein kinases) which leads to

3

enhanced *c-jun* transcription by phosphorylation of JUN at sites that increases its ability to activate transcription. Ectopic expression of a dominant-negative *c-jun* mutant lacking the N terminus or a dominant-negative JNK kinase abolishes stress-induced apoptosis. See Karin, M., Liu, Z.-G., and Zandi, E. "AP-1

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25   Protein tyrosine kinases (PTK) play important roles in the initiation and maintenance of biochemical signal transduction cascades that affect proliferation and survival of B-lineage lymphoid cells. Oxidative stress has been shown to activate BTK, SYK, and Src family PTK. It is known that PTK activation precedes and mandates radiation-induced activation of *c-jun*

30   protooncogene expression in human B-lineage lymphoid cells (Chae, H. P., Jarvis, L. J., and Uckun, F. M. Cancer Res. *53:* 447-51, 1993). However, the identity of the PTK responsible for radiation-induced *c-jun* activation is not yet known. See Uckun, F. M., Waddick, K. G., Mahajan, S., Jun, X., Takata, M.,

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E., Sharpe, A. H., and Berg, L. J." Defects in B lymphocyte maturation and T lymphocyte activation in mice lacking Jak 3," *Science. 270:* 794-797, **1995**; Nosaka, T., Van Deursen, J. M., Tripp, R.A., Thierfelder, W. E., Witthuhn, B. A., McMickle, A. P., Doherty, P. c., Grosveld, G. C., and Ihle, J. N. "Defective

5   lymphoid development in mice lacking Jak 3," *Science. 270:* 800-802, **1995**.

U.S. Patent Application Serial Number 09/087,479 (entitled Quinazolines For Treating Brain Tumor; filed 28 May 1998) discloses hydroxyquinazoline derivatives that exhibit potent cytotoxicity against human glioblastoma cells (i.e. brain tumor cells). Because JAK-3 is not known to be

10   present in these glioblastoma cells, the cytotoxic activity of the hydroxyquinazoline derivatives is not believed to result from inhibition of JAK-3 activity. Additionally, the cytotoxic activity of the hydroxyquinazoline derivatives is not known to result from the inhibition of c-jun activation.

There is currently a need for therapeutic agents and methods that

15   are useful for preventing or reducing cell damage that results from exposure to radiation and chemical agents that cause DNA-damage. There is also a need for chemical agents as well as *in vitro* and *in vivo* methods that can be used to further investigate the biological pathways associated with DNA-damage that results from exposure to radiation or chemical agents.

20

Summary of the Invention

The invention provides a method comprising inhibiting c-jun expression in cells (e.g. mammalian or avian) by contacting the cells (*in vitro* or *in vivo*) with a substance that inhibits the activity of Janus family kinase 3

25   (JAK-3).

The invention also provides a therapeutic method for preventing or treating a pathological condition in a mammal (e.g. a human) wherein c-jun activation is implicated and inhibition of its expression is desired comprising administering to a mammal in need of such therapy, an effective amount of a

30   substance that inhibits the activity of JAK-3.

The invention also provides novel compounds of formula I as well as processes and intermediates useful for their preparation.

6

The invention also provides substances that are effective to inhibit JAK-3 for use in medical therapy (preferably for use in treating conditions that result from exposure to radiation or to chemical agents that cause DNA damage), as well as the use of substances that inhibit JAK-3 for the manufacture of a

5   medicament for the treatment of a condition that is associated with exposure to radiation, or to chemical agents that cause DNA damage.

Brief Description of the Figures

Figure 1. Radiation-induced c-jun activation in wild-type

10   **DT-40 lymphoma B-cells. [A].** *Dose response for induction of c-jun mRNA.* DT-40 chicken cells were irradiated at the indicated doses (0,10,15,20 Gy). Total RNA was extracted after a 2 hours or 4 hours post-irradiation time period. RNA (20 mg) was loaded on a Northern gel and transferred by capillary blotting to a nylon membrane. The Northern blot was hybridized with a ^{32}P labeled chicken

15   c-jun probe (top panel) or a chicken GAPDH probe (bottom panel). The inset shows the values for the c-jun/GAPDH transcript expression ratios as determined with a Bio Rad Storage Phosphor Imager and corresponding SI values **[B].** *Effect of the PTK inhibitor genistein on induction of c-jun mRNA.* Cells were treated with 30 mg/ml of genistein for 24 hours at 37°C prior to exposure to 20

20   Gy ionizing radiation. c-*jun* expression levels were determined as in [A].

Figure 2. Radiation-induced activation of c-*jun* in BTK⁻

DT-40 cells. Two representative experiments (shown in [A] and [B]) showing induction of c-*jun* mRNA expression by ionizing radiation in wild type (WT) and BTK⁻ DT-40 cells. Poly (A)⁺RNA was isolated from non-irradiated cells as

25   well as irradiated cells (20 Gy, with a 2 hours post-radiation recovery period). Northern blots of 2 mg of poly (A)⁺ were hybridized with c-jun probe (*top panel*), (-actin probe (*middle panel* in [A] only), and GAPDH probe (bottom panel). The inset below each panel shows the relative expression of c-jun normalized for RNA load (c-jun/GAPDH ratio) and SI (fold induction over

30   non-irradiated controls).

Figure 3. Induction of *c-jun* mRNA expression by ionizing radiation in wild type and mutant DT-40 cell lines. DT-40, BTK⁻ DT-40, SYK⁻ DT-40 (shown in [A]), as well as LYN⁻ DT-40 and LYN⁻SYK⁻ DT 40

7

cells (shown in [B]) were irradiated with 20 Gy and poly $(A)^+$ RNA (in [A]) or

total RNA (in [B]) was harvested after a 2 hour recovery period. RNA from

non-irradiated cells was used as a control. Northern blots containing 2 mg of

poly $(A)^+$ (in [A]) or 20 mg of total RNA (in [B]) from each cell line were

5   hybridized with both [32] P labeled *c-jun* probe(top panel) and GAPDH probe

(bottom panel). The insets below the panels show the relative expression of

c-jun normalized for RNA loading (*c-jun*/ GAPDH ratios) as well as the SI (fold

induction over non-irradiated controls).

Figure 4. JAK-3 Inhibitors. [A]. Structures of JAK-3

10   inhibitors. [B] Specificity of JAK-3 inhibitors. Sf21 cells infected with

baculovirus expression vectors for JAK-1 JAK-2 or JAK-3 were subjected to

immunoprecipitation with anti-JAK antibodies. JAK-1 (shown in B.1), JAK-2

(shown in B.2) and JAK-3 (shown in B.3 and B.4 which illustrate results from 2

independent experiments) immune complexes were treated with 1% DMSO

15   (vehicle control = CON), Compound 1, or Compound 2 for 1 hour prior to hot

kinase assays, as described (20,22). Both compounds inhibited JAK-3 when used

at 10 µg/ml whereas they did not inhibit JAK-1 or JAK-2 even at 75 µg/ml **[C].**

EMSAs of 32Dc22-IL-2Rβ cells. Compound 1(100 (g/ml) and Compound 2

(100 (g/ml) inhibited IL-2 triggered JAK-3-dependent STAT activation but not

20   IL-3-triggered JAK-1/JAK-2-dependent STAT activation in 32Dc11-IL-2Rβ

cells.

Figure 5. Effects of a JAK-3 inhibitor on c-*jun* induction in

irradiated DT-40 cells. Cells were treated with the quinazoline derivative

4-(3'-Bromo-4'-hydroxyl-phenyl)-amino-6,7-dimethoxyquinazoline (100

25   mg/ml) for 24 hours at 37 °C prior to exposure to 20 Gy ionizing radiation.

c-jun expression levels were determined as outlined in Figures 1-3.

<u>Detailed Description</u>

As used herein, the term "inhibit" means to reduce by a

30   measurable amount, or prevent entirely; and the phrase "inhibit c-jun activation"

includes the inhibition of RNA production and the inhibition of the production of

the protein encoded by the RNA.

8

Applicants examined the potential involvement of BTK, SYK and LYN in radiation-induced *c-jun* activation, using DT-40 chicken lymphoma B-cell clones rendered deficient for these specific PTK by targeted gene disruption. It was found that BTK plays no role in radiation-induced *c-jun*

5   activation. Similarly, neither LYN nor SYK are required for activation of *c-jun* after radiation exposure. However, their participation may influence the magnitude of the *c-jun* response. It was unexpectedly discovered, however, that an inhibitor of Janus family kinase 3 (JAK-3) abrogated radiation-induced *c-jun* activation.

10   C-jun expression can be activated by exposure to chemical agents that damage DNA such as ara-C, a topoisomerase II inhibitors, or alkylating agents. C-jun activation can also result from exposure to ultraviolet radiation or ionizing radiation. According to the invention, inhibitors of JAK-3 can be used to inhibit c-jun expression resulting from exposure to radiation or exposure to

15   chemical agents.

The methods of the invention can be carried out *in vitro*. Such *in vitro* methods are also useful for studying the biological processes associated with cell response to DNA damaging agents. The methods of the invention can also be carried out *in vivo*. Such methods can also be used to study the

20   biological processes associated with cell response to DNA damaging agents, as well as for treating pathological conditions in mammals (e.g. humans) that result from exposure to DNA-damaging agents.
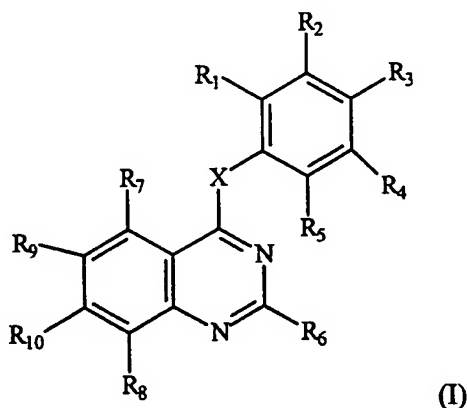
Pathological conditions that result from exposure to DNA-damaging agents include conditions that result from oxidative stress, such as

25   tissue or organ (e.g. heart, liver, or kidney) damage, inflammation, and hair loss, as well as the negative effects that are produced by oxygen free radicals during chemotherapy. Oxidative stress may result from exposure to external agents, or may result from internal processes. Thus, JAK-3 inhibitors are also useful for treating conditions resulting from the action of internally generated oxygen free

30   radicals, such as aging and amyelotrophic lateral sclerosis (ALS).

According to the invention, the JAK-3 inhibitors may be administered prophylactically, i.e. prior to exposure to the DNA-damaging

agent, or the JAK-3 inhibitors may be administered after exposure to the DNA
damaging agent.

The JAK-3 inhibitors useful in the methods of the invention
include all compounds capable of inhibiting the activity of JAK-3, it being well
5   known in the art how to measure a compounds ability to inhibit JAK-3, for
example, using standard tests similar to the test described hereinbelow in
Example 2 under the heading "Effects of a JAK-3 inhibitor on radiation-induced
c-jun activation in DT40 cells."

JAK-3 inhibitors that are useful in the methods of the invention
10   include compounds of formula I:

(I)

wherein

X is HN, $R_{11}N$, S, O, CH_2, or $R_{11}CH$;

R_{11} is hydrogen, (C_1-C_4)alkyl, or (C_1-C_4)alkanoyl;

15   R_1-R_8 are each independently hydrogen, hydroxy, mercapto, amino, nitro,
(C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; wherein two adjacent
groups of R_1-R_5 together with the phenyl ring to which they are attached may
optionally form a fused ring, for example forming a naphthyl or a
tetrahydronaphthyl ring; and further wherein the ring formed by the two adjacent
20   groups of R_1-R_5 may optionally be substituted by 1, 2, 3, or 4 hydroxy, mercapto,
amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; and

R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, (C_1-C_4)alkoxy,
halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a
pharmaceutically acceptable salt thereof.

The following definitions are used, unless otherwise described: halo is fluoro, chloro, bromo, or iodo. Alkyl, alkanoyl, etc. denote both straight and branched groups; but reference to an individual radical such as "propyl" embraces only the straight chain radical, a branched chain isomer such as

5   "isopropyl" being specifically referred to. (C_1-C_4)Alkyl includes methyl, ethyl, propyl, isopropyl, butyl, iso-butyl, and sec-butyl; (C_1-C_4)alkoxy includes methoxy, ethoxy, propoxy, isopropoxy, butoxy, iso-butoxy, and sec-butoxy; and (C_1-C_4)alkanoyl includes acetyl, propanoyl and butanoyl.

A specific group of compounds are compounds of formula I

10   wherein R_1-R_5 are each independently hydrogen, mercapto, amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halogen.

Another specific group of compounds are compounds of formula I wherein R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a

15   pharmaceutically acceptable salt thereof.

JAK-3 inhibitors that are useful in the methods of the invention also include compounds of formula I as described in U.S. Patent Application Serial Number 09/087,479 (entitled Quinazolines For Treating Brain Tumor; filed 28 May 1998).

20   Preferred JAK-3 inhibitors include 4-(4'-hydroxylphenyl)-amino-6,7-dimethoxyquinazoline and 4-(3'-bromo-4'-hydroxylphenyl)-amino-6,7-dimethoxyquinazoline, or a pharmaceutically acceptable salt thereof.

Substances that inhibit JAK-3 ("the Substance(s)") can be formulated as pharmaceutical compositions and administered to a mammalian

25   host, such as a human patient in a variety of forms adapted to the chosen route of administration, i.e., orally or parenterally, by intravenous, intramuscular, topical or subcutaneous routes.

Thus, the Substances may be systemically administered, e.g., orally, in combination with a pharmaceutically acceptable vehicle such as an

30   inert diluent or an assimilable edible carrier. They may be enclosed in hard or soft shell gelatin capsules, may be compressed into tablets, or may be incorporated directly with the food of the patient's diet. For oral therapeutic administration, the Substance may be combined with one or more excipients and

used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. Such compositions and preparations should contain at least 0.1% of the Substance. The percentage of the compositions and preparations may, of course, be varied and may conveniently

5   be between about 2 to about 60% of the weight of a given unit dosage form. The amount of Substance in such therapeutically useful compositions is such that an effective dosage level will be obtained.

The tablets, troches, pills, capsules, and the like may also contain the following: binders such as gum tragacanth, acacia, corn starch or gelatin;

10   excipients such as dicalcium phosphate; a disintegrating agent such as corn starch, potato starch, alginic acid and the like; a lubricant such as magnesium stearate; and a sweetening agent such as sucrose, fructose, lactose or aspartame or a flavoring agent such as peppermint, oil of wintergreen, or cherry flavoring may be added. When the unit dosage form is a capsule, it may contain, in

15   addition to materials of the above type, a liquid carrier, such as a vegetable oil or a polyethylene glycol. Various other materials may be present as coatings or to otherwise modify the physical form of the solid unit dosage form. For instance, tablets, pills, or capsules may be coated with gelatin, wax, shellac or sugar and the like. A syrup or elixir may contain the active compound, sucrose or fructose

20   as a sweetening agent, methyl and propylparabens as preservatives, a dye and flavoring such as cherry or orange flavor. Of course, any material used in preparing any unit dosage form should be pharmaceutically acceptable and substantially non-toxic in the amounts employed. In addition, the Substance may be incorporated into sustained-release preparations and devices.

25   The Substances may also be administered intravenously or intraperitoneally by infusion or injection. Solutions of the Substance can be prepared in water, optionally mixed with a nontoxic surfactant. Dispersions can also be prepared in glycerol, liquid polyethylene glycols, triacetin, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these

30   preparations contain a preservative to prevent the growth of microorganisms.

The pharmaceutical dosage forms suitable for injection or infusion can include sterile aqueous solutions or dispersions or sterile powders comprising the Substance which are adapted for the extemporaneous preparation

of sterile injectable or infusible solutions or dispersions, optionally encapsulated in liposomes. In all cases, the ultimate dosage form must be sterile, fluid and stable under the conditions of manufacture and storage. The liquid carrier or vehicle can be a solvent or liquid dispersion medium comprising, for example,

5   water, ethanol, a polyol (for example, glycerol, propylene glycol, liquid polyethylene glycols, and the like), vegetable oils, nontoxic glyceryl esters, and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the formation of liposomes, by the maintenance of the required particle size in the case of dispersions or by the use of surfactants. The prevention of the action

10   of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, buffers or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of

15   agents delaying absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating the Substance in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filter sterilization. In the case of sterile powders for the preparation of sterile injectable solutions,

20   the preferred methods of preparation are vacuum drying and the freeze drying techniques, which yield a powder of the active ingredient plus any additional desired ingredient present in the previously sterile-filtered solutions.

For topical administration, the Substances may be applied in pure form, i.e., when they are liquids. However, it will generally be desirable to

25   administer them to the skin as compositions or formulations, in combination with a dermatologically acceptable carrier, which may be a solid or a liquid.

Useful solid carriers include finely divided solids such as talc, clay, microcrystalline cellulose, silica, alumina and the like. Useful liquid carriers include water, alcohols or glycols or water-alcohol/glycol blends, in

30   which the Substances can be dissolved or dispersed at effective levels, optionally with the aid of non-toxic surfactants. Adjuvants such as fragrances and additional antimicrobial agents can be added to optimize the properties for a given use. The resultant liquid compositions can be applied from absorbent

pads, used to impregnate bandages and other dressings, or sprayed onto the affected area using pump-type or aerosol sprayers.

Thickeners such as synthetic polymers, fatty acids, fatty acid salts and esters, fatty alcohols, modified celluloses or modified mineral materials can

5   also be employed with liquid carriers to form spreadable pastes, gels, ointments, soaps, and the like, for application directly to the skin of the user.

Examples of useful dermatological compositions which can be used to deliver the Substances to the skin are known to the art; for example, see Jacquet et al. (U.S. Pat. No. 4,608,392), Geria (U.S. Pat. No. 4,992,478), Smith

10   et al. (U.S. Pat. No. 4,559,157) and Wortzman (U.S. Pat. No. 4,820,508).

Useful dosages of the compounds of formula I can be determined by comparing their *in vitro* activity, and *in vivo* activity in animal models. Methods for the extrapolation of effective dosages in mice, and other animals, to humans are known to the art; for example, see U.S. Pat. No. 4,938,949.

15   Generally, the concentration of the Substance in a liquid composition, such as a lotion, will be from about 0.1-25 wt-%, preferably from about 0.5-10 wt-%. The concentration in a semi-solid or solid composition such as a gel or a powder will be about 0.1-5 wt-%, preferably about 0.5-2.5 wt-%.

The amount of the Substance required for use in treatment will

20   vary not only with the particular salt selected but also with the route of administration, the nature of the condition being treated and the age and condition of the patient and will be ultimately at the discretion of the attendant physician or clinician.

In general, however, a suitable dose will be in the range of from

25   about 0.5 to about 100 mg/kg, e.g., from about 10 to about 75 mg/kg of body weight per day, such as 3 to about 50 mg per kilogram body weight of the recipient per day, preferably in the range of 6 to 90 mg/kg/day, most preferably in the range of 15 to 60 mg/kg/day.

The Substance is conveniently administered in unit dosage form;

30   for example, containing 5 to 1000 mg, conveniently 10 to 750 mg, most conveniently, 50 to 500 mg of active ingredient per unit dosage form.

Ideally, the Substance should be administered to achieve peak plasma concentrations of from about 0.5 to about 75 μM, preferably, about 1 to

50 μM, most preferably, about 2 to about 30 μM. This may be achieved, for example, by the intravenous injection of a 0.05 to 5% solution of the Substance, optionally in saline, or orally administered as a bolus containing about 1-100 mg of the Substance. Desirable blood levels may be maintained by continuous

5 infusion to provide about 0.01-5.0 mg/kg/hr or by intermittent infusions containing about 0.4-15 mg/kg of the Substance.

The Substance may conveniently be presented in a single dose or as divided doses administered at appropriate intervals, for example, as two, three, four or more sub-doses per day. The sub-dose itself may be further divided, e.g.,

10 into a number of discrete loosely spaced administrations; such as multiple inhalations from an insufflator or by application of a plurality of drops into the eye.

The invention will now be illustrated by the following non-limiting Examples.
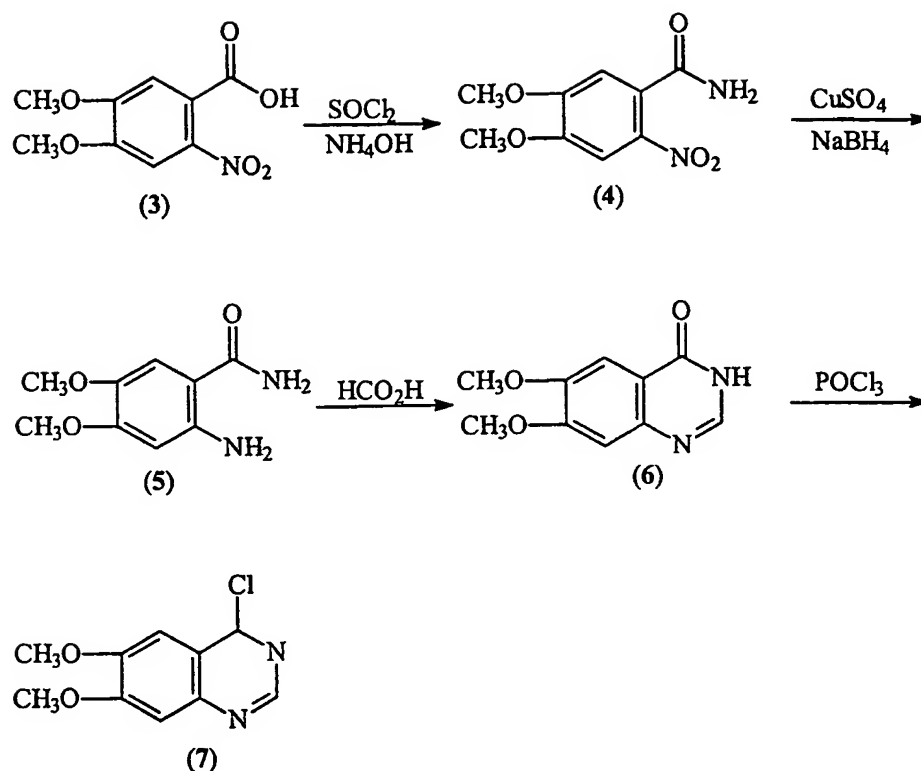
15

15

Examples

Example 1. Chemical synthesis and Characterization of JAK-3 Inhibitors

5

Melting points are uncorrected. ^{1}H NMR spectra were recorded using a Varian Mercury 300 spectrometer in DMSO-d$_6$ or CDCl$_3$. Chemical shifts are reported in parts per million (ppm) with tetramethylsilane (TMS) as an internal standard at zero ppm. Coupling constant (J) are given in hertz and the abbreviations s, d, t, q, and m refer to singlet, doublet, triplet, quartet and multiplet, respectively. Infrared spectra were recorded on a Nicolet PROTEGE 460-IR spectrometer. Mass spectroscopy data were recorded on a FINNIGAN MAT 95, VG 7070E-HF G.C. system with an HP 5973 Mass Selection Detector. UV spectra were recorded on BECKMAN DU 7400 and using MeOH as the solvent. TLC was performed on a precoated silica gel plate (Silica Gel KGF; Whitman Inc). Silica gel (200-400 mesh, Whitman Inc.) was used for all column chromatography separations. All chemicals were reagent grade and were purchased from Aldrich Chemical Company (Milwaukee, Wis) or Sigma Chemical Company (St. Louis, MO).

The common synthetic precursor 4-chloro-6,7-dimethoxyquinazoline (7), used for preparing compounds (1) and (2), was prepared using liturature procedures as illustrated in Scheme 1.

16

Scheme 1

4,5-Dimethoxy-2-nitrobenzoic acid (3) was treated with thionyl chloride and then reacted with ammonia to give

5   4,5-dimethoxy-2-nitrobenzamide (4) as described by F. Nomoto et al. *Chem. Pharm. Bull.* **1990**, *38*, 1591-1595. The nitro group in compound (4) was reduced with sodium borohydride in the presence of copper sulfate (see C.L. Thomas *Catalytic Processes and Proven Catalysts* Academic Press, New York (1970)) to give 4,5-dimethoxy-2-aminobenzamide (5) which was cyclized by

10   refluxing with formic acid to give 6,7-dimethoxyquinazoline-4(3H)-one (6). Compound (6) was refluxed with phosphorus oxytrichloride to provide the common synthetic precursor (7).

Compounds 1 and 2 (Figure 4) were prepared from the common synthetic precursor (7) and the requsite aniline as follows.

17

4-(4 '-Hydroxylphenyl)-amino-6,7-dimethoxyquinazoline (1). A
mixture of 448 mg (2 mmol) of 4-chloro-6,7-dimethoxy-quinazoline (7) and 2.5
mmol of 4-hydroxyaniline in 20 ml of alcohol (EtOH or MeOH) was refluxed
for 8 hours. After cooling triethylamine was added to basify the solution, and

5   the solvent was concentrated to give material that was recrystallized from DMF
to give compound (1); 84.29%; m.p. 245.0- 248.0 °C; ^{1}H NMR (DMSO-d$_6$): δ
11.21(s, 1H, -NH), 9.70(s, 1H, -OH), 8.74(s, 1H, 2-H), 8.22(s, 1H, 5-H), 7.40(d,
2H, J = 8.9 Hz, 2',6'-H), 7.29(s, 1H, 8-H), 6.85(d, 2H, J = 8.9 Hz, 3',5'-H),
3.98(s, 3H, -OCH$_3$), 3.97(s, 3H, -OCH$_3$). UV(MeOH) λ_{max}(e): 203.0, 222.0 ,

10   251.0, 320.0 nm. IR(KBr)u$_{max}$: 3428, 2836, 1635, 1516, 1443, 1234 cm^{-1}.
GC/MS m/z 298 (M$^+$+1, 100.00), 297(M$^+$, 26.56), 296(M$^+$-1, 12.46).

4-(3 '-Bromo-4 '-hydroxylphenyl)-amino-6,7-dimethoxy-
quinazoline (2). A mixture of 448 mg (2 mmol) of 4-chloro-6,7-dimethoxy-
quinazoline (7) and 2.5 mmol of 3-bromo-4-hydroxyaniline in 20 ml of alcohol

15   (EtOH or MeOH) was refluxed for 8 hours. After cooling, triethylamine was
added to basify the solution, and the solvent was concentrated to give material
that was recrystallized from DMF to give compound (2); 89.90%; m.p.
233.0-233.5 °C; ^{1}H NMR(DMSO-d$_6$): δ 10.08(s, 1H, -NH), 9.38(s, 1H , -OH),
8.40(s, 1H, 2-H), 7.89(d, 1H, $J_{2',5'}$ = 2.7 Hz, 2'-H), 7.75(s, 1H, 5-H), 7.55(dd,

20   1H, $J_{5',6'}$ = 9.0 Hz, $J_{2',6'}$ = 2.7 Hz, , 6'-H), 7.14(s, 1H, 8-H), 6.97(d, 1H, $J_{5',6'}$ =
9.0 Hz, 5'-H), 3.92(s, 3H, -OCH$_{ER}$), 3.90(s, 3H, -OCH$_3$). UV(MeOH)λ_{max}(e):
203.0, 222.0 , 250.0, 335.0 nm. IR(KBr)u$_{max}$: 3431(br), 2841, 1624, 1498, 1423,
1244 cm^{-1}. GC/MS m/z 378(M$^+$ +2, 90.68), 377(M$^+$ +1,37.49), 376(M$^+$,100.00),
360(M$^+$3.63), 298(18.86), 282 (6.65).

25

18

Example 2. **Biological Screening**

MATERIALS AND METHODS

        Cell Lines. The establishment and characterization of

5   BTK-deficient, SYK-deficient, and LYN-deficient clones and reconstituted

SYK-deficient cell lines of DT-40 chicken lymphoma B-cells were previously

reported. The culture medium was RPMI 1640 (Life Technologies;

Gaithersburg, MD), supplemented with 1% chicken serum (Sigma; St. Louis,

MO), 5% fetal bovine serum (Hyclone, Logan,UT) and 1%

10   penicillin-streptomycin (Life Technologies). See Uckun, F. M., Waddick, K. G.,

Mahajan, S., Jun, X., Takata, M., Bolen, J., and Kurosaki, T. *Science. 273:*

1096-100, **1996**; Kurosaki, T. *Curr Opin Immunol. 9:* 309-18, **1997**; Kurosaki,

T., Johnson, S. A., Pao, L., Sada, K., Yamamura, H., and Cambier, J. C. *J. Exp.*

Med. 182: 1815-1823, **1995**; and Dibirdik I., Kristupaitis D., Kurosaki T.,

15   Tuel-Ahlgren L., Chu A., Pond D., Tuong D., Luben R., Uckun F.M. *J. Biol.*

Chem. 273(7), pp:4035-4039, **1998**.

        Use of PTK Inhibitors. Cells (2×10^6/ml) were treated for 24

hours at 37 °C with either (1) the PTK inhibitory isoflavone genistein

(Calbiochem, La Jolla, CA) at 111 mM (30 mg/ml) concentration or (2) the

20   Janus family kinase, 3 (JAK-3)-specific PTK inhibitor

4-(3'-bromo-4'-hydroxyphenyl)-amino-6,7-dimethoxyquinazoline,

$C_{16}H_{14}Br(N_3O_3)$, kindly provided by Dr. Xing-Ping Liu, Alexander and Parker

Pharmaceutical Inc., Roseville, MN) at 270 mM (100 mg/ml) prior to radiation

in order to assess the effects of these agents on radiation-induced c-*jun*

25   activation.

        Irradiation of cells. Cells (2×10^6 cells/ml) in plastic tissue

culture flasks were irradiated with 10-20 Gy at a dose rate of 4 Gy/min during

log phase growth and under aerobic conditions using a ^{137}Cs irradiator (J.L.

Shephard, Glendale, CA, as previously described by Tuel Ahlgren, L., Jun, X.,

30   Waddick, K. G., Jin, J., Bolen, J., and Uckun, F. M. "Role of tyrosine

phosphorylation in radiation-induced cell cycle-arrest of leukemic B-cell

precursors at the G2-M transition checkpoint," *Leuk Lymphoma. 20:* 417-26,

1996; and Uckun, F.M., Jaszcz, W., Chandan Langlie, M., Waddick, K.G., Gajl

19

Peczalska, K. and Song, C.W. "Intrinsic radiation resistance of primary

clonogenic blasts from children with newly diagnosed B-cell precursor acute

lymphoblastic leukemia," *J Clin Inves*. 91:1044-1051, **1993**. In some

experiments, cells were preincubated with PTK inhibitors for 24 hours prior to

5   irradiation.

          c-jun probe. A 506 basepair (bp) *c-jun* probe was obtained by

polymerase chain reaction (PCR) amplification of chicken genomic DNA.

Primer sequences were determined based upon the sequence of chicken *c-jun*

(GenBank accession code CHKJUN). Two primers: 5'-ACTCTGCACC

10   CAACTACAACGC-3' (SEQ. ID NO: 1) and 5'-CTTCTACCGT

CAGCTTTACGCG-3' (SEQ ID NO: 2) were used for amplification.

Amplification was performed with a mix of Taq polymerase and a proof reading

polymerase (eLONGase:*Taq* polymerase plus *Pyrococcus species* GB-D

polymerase, Gibco BRL, Grand Island, NY) on an thermocycler, Ericomp Delta

15   II cycler, using a hot start. PCR products were subsequently cloned into the

cloning vector, PCR 2.1 (Invitrogen, San Diego, CA). An insert of the proper

size (506 basepair) was identified as chicken *c-jun* by sequence analysis using

PRISM dye terminator cycle sequencing (AmpliTaq® DNA Polymerase, FS) and

analyzed on an automated sequencer, ALF express sequencer (Pharmacia

20   Biotech, Piscataway, NJ). A 538 base pair chicken glyceraldehyde 3-phosphate

dehydrogenase (GAPDH) probe was generated by reverse transcription and

subsequent PCR amplification (RT-PCR) from chicken RNA with the following

primers: 5'-AGAGGTGCTGCCCAGAACATCATC-3' (SEQ ID NO: 3) and

5'-GTGGGGAGACAGAAGGGAACAGA-3' (SEQ ID NO: 4). A 413 bp

25   chicken B-actin probe was generated by RT-PCR amplification from chicken

RNA with the following primers: 5'-GCCCTCTTCCAGCATCTTTCTT-3'

(SEQ ID NO: 5) and 5'-TTTATGCGCATTTATGGGTT-3' (SEQ ID NO: 6).

The amplified cDNAs were cloned into PCR 2.1.

          RNA isolation and Northern blot hybridization analysis.

30   Total RNA was extracted from approximately 2.5×10^7 cells with Trizol

Reagent, a monophasic solution of phenol and guanidine isothiocyanate as

described by Chomcznski, P. and Sacchi, N. "Single-step method of RNA

isolation by guanidinium-thiocyanate-phenol-chloroform extraction," *Anal.*

20

Biochem. 162: 156-159, **1987**. Poly (A)⁺ RNA was isolated directly from 1-3 x

10⁸ cells with an Invitrogen Fast Trak 2.0 mRNA isolation kit. In brief, cells

were lysed in a sodium dodecyl sulfate (SDS) lysis buffer containing a

proprietary mixture of proteases. The lysate was directly incubated with oligo-dT

5   for absorption and subsequent elution of poly (A)⁺ RNA.

Two micrograms of poly (A)⁺ or 20 micrograms of total RNA

were denatured in formaldehyde/formamide loading dye at 65° prior to loading

onto a 1% agarose-formaldehyde denaturing gel. Transcript sizes were

determined relative to RNA markers of 0.5-9 kb. The gels were stained with

10   Radiant Red in H₂O to check loading and integrity of RNA prior to transfer. The

RNA was subsequently transferred to positively charged nylon membrane with

20X standard sodium citrate(SSC) transfer buffer (1XSSC= 0.15 M sodium

chloride-0.015 M sodium citrate) by downward capillary transfer. The *c-jun*

fragment was radiolabeled by random priming with [(-³²P]-dCTP (3000 Ci/mM)

15   [Amersham, Arlington Heights, IL] (40). Northern blots were hybridized

overnight at 42 °C in prehybridization/hybridization solution (50% formamide

with proprietary blocking and background reduction reagents; Ambion, Austin,

TX) for 16-24 hours and unbound probe was removed by washing to a final

stringency of 0.1% SDS, 0.1XSSC (65 °C). The blots were analyzed both by

20   autoradiography and using the BioRad Storage Phosphor Imager System

(BioRad, Hercules, CA) for quantitative scanning. The blots were subsequently

stripped in boiling 0.1% SDS, and then rehybridized with a chicken GAPDH

and/or chicken (β-actin probe to normalize for loading differences.

25   RESULTS AND DISCUSSION

Exposure of DT-40 chicken lymphoma B-cells to ionizing

radiation activates the *c-jun* protooncogene. Exposure of human lymphoma

B-cells to 10-20 Gy-rays results in enhanced *c-jun* expression with a maximum

response at 1-2 hours (Chae, H. P., Jarvis, L. J., and Uckun, F. M. *Cancer Res.*

30   *53:* 447-51, **1993**). It has also been reported that ionizing radiation triggers in

DT-40 chicken lymphoma B-cells biochemical and biological signals similar to

those in human lymphoma B-cells (Uckun, F. M., Waddick, K. G., Mahajan, S.,

Jun, X., Takata, M., Bolen, J., and Kurosaki, T. *Science. 273:* 1096-100, **1996**).

21

In order to determine if DT-40 chicken lymphoma B-cells show a similar *c-jun*
response to ionizing radiation, DT-40 cells were irradiated with 5,10,15 or 20
Gy and examined total RNA harvested from cells 2 or 4 hours after radiation
exposure for expression levels of 1.8 kb chicken *c-jun* transcripts by quantitative

5   Northern blot analysis. As shown in Figure 1A, radiation exposure increased the
level of *c-jun* transcripts in a dose-and time-dependent manner without
significantly affecting the GAPDH transcript levels with a maximum stimulation
index (SI) [as determined by comparison of the c-jun/GAPDH ratios in
non-irradiated versus irradiated cells] of 3.1, 4 hours after 20 Gy. In seven

10   additional independent experiments, the stimulation index for 20 Gy ionizing
radiation at 2 hours after radiation exposure ranged from 2.4 to 3.8 (mean (SE =
2.9 ± 0.4).

The role of PTK in radiation-induced activation of *c-jun*
expression in chicken lymphoma B cells was examined next, since PTK

15   inhibitors were shown to prevent radiation-induced *c-jun* activation in human
lymphoma B-cells. As shown in Figure 1B, ionizing radiation did not
significantly enhance *c-jun* expression levels in DT-40 cells treated with the
PTK-inhibitory isoflavone, genistein (stimulation index=1.1) indicating that
activation of a PTK is required for radiation-induced *c-jun* expression in chicken

20   lymphoma B cells as well. These findings established DT-40 chicken lymphoma
B-cells as a suitable model to further elucidate the molecular mechanism of
radiation-induced *c-jun* activation.

**Cytoplasmic protein tyrosine kinases BTK, LYN, and SYK
are not required for radiation induced *c-jun* activation.** BTK is abundantly

25   expressed in lymphoma B-cells and its activation has been shown to be required
for radiation-induced apoptosis of DT-40 cells (Uckun, F. M., Waddick, K. G.,
Mahajan, S., Jun, X., Takata, M., Bolen, J., and Kurosaki, T. *Science. 273:*
1096-100, **1996**). DT-40 cells rendered BTK-deficient by targeted disruption of
the BTK genes do not undergo apoptosis after radiation exposure. Therefore, we

30   set out to determine if BTK could be the PTK responsible for radiation-induced
c-jun activation as well, by comparing the levels of *c-jun* induction in
BTK-deficient (BTK⁻) versus wild-type DT-40 cells. Contrary to our
expectations, 20 Gy ionizing radiation did not fail to induce *c-jun* expression in

BTK-deficient DT-40 cells in any of the three independent experiments performed. The stimulation indices ranged from 1.6 to 3.9 (mean ± SE = 2.4 ± 0.5) (Figure 2). Thus, ionizing radiation-induced increases in *c-jun* transcript levels do not depend upon the presence of BTK.

5   Since SYK is also abundantly expressed in DT-40 cells and is rapidly activated after ionizing radiation, we next examined if SYK might be the PTK responsible for radiation-induced increases in *c-jun* transcript levels. As shown in Figure 3A, 20 Gy ionizing radiation enhanced *c-jun* expression in SYK⁻ DT-40 cells rendered SYK-deficient by targeted gene disruption even

10 though the stimulation indices observed in five independent experiments were lower than from those in wild-type cells (1.9 ± 0.2, vs 2.9 ± 0.4, $p < 0.01$). Thus, SYK is not required for radiation-induced *c-jun* activation in DT-40 cells but it may participate in generation of an optimal signal.

       DT-40 cells express high levels of LYN but do not express other

15 members of the Src PTK family, including BLK, HCK, SRC, FYN, or YES at detectable levels (see Uckun, F. M., Waddick, K. G., Mahajan, S., Jun, X., Takata, M., Bolen, J., and Kurosaki, T. *Science. 273*: 1096-100, **1996**; Kurosaki, T., Johnson, S. A., Pao, L., Sada, K., Yamamura, H., and Cambier, J. C. "Role of the Syk autophosphorylation site and SH2 domains in B cell antigen receptor

20 signaling," *J. Exp. Med. 182*: 1815-1823, **1995**; and Takata, M., Homma, Y., and Kurosaki, T. "Requirement of phospholipase C-γ2 activation in surface immunoglobulin M-induced B cell apoptosis.," *J Exp Med. 182*: 907-914, **1995**. Since it has previously been demonstrated that SRC family PTK are essential for UV-stimulated increases in *c-jun* expression, we postulated that the predominant

25 SRC-family member, LYN, might mediate radiation-induced *c-jun* expression in DT-40 cells. To test this hypothesis, we examined the ability of ionizing radiation to activate *c-jun* expression in DT-40 cells rendered LYN-deficient by targeted gene disruption. LYN-deficient (LYN⁻) cells showed enhanced *c-jun* expression after irradiation, however the stimulation indices were lower than

30 those in wild-type DT-40 (Figure 3B). Since LYN and SYK have been shown to cooperate in the generation of other signals in B-cells (see Kurosaki, T. "Molecular mechanisms in B cell antigen receptor signaling," *Curr Opin Immunol. 9*: 309-18, **1997**), the ability of ionizing radiation to induce *c-jun*

23

expression in LYN⁻SYK⁻ DT-40 cells, generated by targeted disruption of the *syk* gene in LYN⁻ deficient DT-40 cells was examined. As shown in Figure 3B, LYN⁻SYK⁻ DT-40 cells showed elevated *c-jun* transcript levels after irradiation, indicating that the *c-jun* response does not depend on either of these PTK, either
5   alone or in cooperation. Similar to SYK, LYN is not required for radiation-induced *c-jun* activation in DT-40 cells but it may participate in generation of an optimal response.

          Interestingly, in four independent experiments, we observed higher baseline expression levels of *c-jun* in SYK⁻ DT-40 cells than in wild-type
10   DT-40 cells (Range: 1.4 - 2.3-fold, mean ± SE = 1.6 ± 0.2-fold), suggesting that Syk may be involved in regulation of baseline *c-jun* levels. To further explore this possibility, we compared *c-jun* levels in SYK⁻ cells to those of SYK⁻ cells reconstituted with wild-type or kinase domain mutant (K⁻) *syk* gene. We observed that reconstitution with wild-type *syk* reduced the higher baseline
15   expression levels of *c-jun* in SYK⁻ cells, whereas reconstitution with a K⁻ *syk* failed to reduce *c-jun* levels (data not shown). These results implicate SYK as a negative regulator of *c-jun* expression. This novel function of SYK seems to depend on its kinase domain.

          Effects of a JAK-3 inhibitor on radiation-induced c-jun
20   **activation in DT40-cells.** B-cell signal transduction events direct fundamental decisions regarding cell survival during periods of oxidative stress. A better understanding of the dynamic interplay between B-cell signaling pathways is needed to determine how vital decisions are dictated during intracellular oxidation changes. STAT proteins (signal transducers and activators of
25   transcription) are a family of DNA binding proteins that were identified during a search for interferon (IFN) a- or g-stimulated gene transcription targets. There are presently seven STAT family members. The JAK family of cytoplasmic protein kinases were originally demonstrated to also function in IFN signaling, and are now known to participate in a broad range of receptor-activated signal
30   cascades. Different ligands and cell activators employ specific JAK and STAT family members. The basic model for STAT activation suggests that in unstimulated cells, latent forms of STATs are predominantly localized within the cytoplasm. Ligand binding induces STAT proteins to associate with intracellular

phosphotyrosine residues of transmembrane receptors. Once STATs are bound
to receptors, receptor-associated JAK kinases phosphorylate the STAT proteins.
STAT proteins then dimerize through specific reciprocal SH2-phosphotyrosine
interactions and may form complexes with other DNA-binding proteins. STAT

5   complexes translocate to the nucleus and interact with DNA response elements
to enhance transcription of target genes. Signaling events regulating apoptotic
responses have been shown to utilize STAT proteins. Notably, a recent study
demonstrated JAK activation by tyrosine phosphorylation in cells that are
exposed to reactive oxygen intermediates, which in-turn lead to tyrosine

10   phosphorylation and activation of STAT-1, STAT-3 and STAT-6.

            After establishing that LYN, BTK, and SYK kinases are not
required for radiation-induced c-jun activation, we set out to determine if c-jun
activation is functionally linked to the JAK-STAT pathway. To this end, we
examined the effects of a JAK-3 inhibitory novel quinazoline derivative on c-jun

15   expression levels in irradiated DT-40 cells. To identify a potent JAK-3 specific
inhibitor, the effects of two novel quinazoline derivatives on the enzymatic
activity of JAK-1, JAK-2, and JAK-3 were examined using Sf21 cells that were
infected with baculovirus expression vectors for these kinases, using standard
methods (Figure 4). Infected cells were harvested, JAKs were

20   immunoprecipitated with appropriate antibodies (anti-JAK-1: (HR-785), cat#
sc-277, rabbit polyclonal IgG affinity purified, 0.1 mg/ml, Santa Cruz
Biotechnology; anti-JAK-2: (C-20)-G, cat # sc-294-G, goat polyclonal IgG
affinity purified, 0.2 mg/ml, Santa Cruz Biotechnology; anti-JAK-3: (C-21), cat
sc-513, rabbit polyclonal IgG affinity purified, 0.2 mg/ml, Santa Cruz

25   Biotechnology), and kinase assays were performed following a 1 hour exposure
of the immunoprecipitated Jaks to the quinazoline compounds, as described by
Uckun, F. M., Waddick, K. G., Mahajan, S., Jun, X., Takata, M., Bolen, J., and
Kurosaki, T. *Science. 273:* 1096-100, 1996; Uckun F.M, Evans W.E, Forsyth
C.J, Waddick K.G, T-Ahlgren L., Chelstrom L.M, Burkhardt A., Bolen J., Myers

30   D.E. *Science* 267:886-891, 1995; and Myers D.E., Jun X., Waddick K.G.,
Forsyth C., Chelstrom L.M., Gunther R.L., Tumer N.E, Bolen J., Uckun F.M.
Proc Nat'l Acad Sci USA 92: 9575-9579, 1995; and Tuel Ahlgren, L., Jun, X.,

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Waddick, K. G., Jin, J., Bolen, J., and Uckun, F. M. *Leuk Lymphoma. 20:*
417-26, 1996.

As shown in Figure 4B, both compounds inhibited JAK-3
(Figures B.3 and B.4) but not JAK-1 (Figure B.1) or JAK-2 (Figure B.2) (Figure

5   4D). Electrophoretic Mobility Shift Assays (EMSAs) were performed to
examine the effects of both compounds on cytokine-induced STAT activation.
Specifically, 32Dc11/IL2Rβ cells (gift from James Ihle, St. Jude Children's
Research Hospital) were exposed at 8×10^6/ml in RPMI supplemented with FBS
to the JAK-3 inhibitors at a final concentration of 10 μg/ml in 1% DMSO) for 1

10   hour and subsequently stimulated with IL2 or IL3 as indicated. Cells were
collected after 15 minutes and resuspended in lysis buffer (100 mM Tris-HCl pH
8.0, 0.5% NP-40, 10% glycerol, 100 mM EDTA, 0.1 mM NaVO3, 50 mM NaF,
150 mM Nacl, 1 mM DTT, 3 (g/ml Aprotinin, 2 g/ml Pepstatin A, 1 (g/ml
Leupeptin and 0.2 mM PMSF). Lysates were precleared by centrifugation for 30

15   minutes. Cell extracts (approximately 10 g) were incubated with 2 μg of
poly(dI-dC) for 30 minutes, followed by a 30 minute incubation with 1 ng of
poly nucleotide kinase-^{32}P labeled double stranded DNA oligonucleotide
representing the IRF-1 STAT DNA binding sequence (Santa Cruz
Biotechnology, Santa Cruz, CA). Samples were resolved by nondenaturing

20   PAGE and visualized by autoradiography. As shown in Figure 4C, both
compounds inhibited the JAK-3-dependent STAT activation after stimulation
with IL-2, but they did not affect the JAK-1/JAK-2-dependent STAT activation
after stimulation with IL-3. Compound 2 was selected for further experiments
designed to examine the effects of JAK-3 inhibition on radiation-induced c-jun

25   activation.

As shown in Figure 5, ionizing radiation failed to induce c-jun
expression in DT-40 cells treated with the JAK-3 inhibitor. This demonstrates
that JAK-3 inhibitors are capable of inhibiting radiation induced c-jun
expression.

30   In untreated cells, c-jun expression is induced by exposure to
DNA-damaging chemical agents and by exposure to radiation. Thus, c-jun
expression is an early marker of cellular response to such DNA-damaging
agents. It has been shown that compounds that inhibit JAK-3 are capable of

26

inhibiting the expression of c-jun. Accordingly, JAK-3 inhibitors may be useful to prevent or treat diseases or conditions that result from exposure to DNA-damaging agents.

       JAK-3 maps to human chromosome 19p12-13.1. A cluster of

5   genes encoding protooncogenes and transcription factors is also located near this region. JAK-3 expression has been demonstrated in mature B-cells as well as B-cell precursors. JAK-3 has also been detected in leukemic B-cell precursors and lymphoma B-cells. The physiological roles for JAK-3 have been borne out through targeted gene disruption studies in mice, the genetic analysis of patients

10   with severe combined immunodeficiency, and biochemical studies of JAK-3 in cell lines. A wide range of stimuli result in JAK-3 activation in B-cells, including interleukin 7 and interleukin 4. The B-cell marker CD40 constitutively associates with JAK-3 and ligation of CD40 results in JAK-3 activation which has been shown to be mandatory for CD40-mediated gene

15   expression. Constitutive activity of JAK-3 has been observed in v-abl transformed pre-B cells and coimmunoprecipitations show that v-abl physically associates with JAK-3 implicating JAK-3 in v-abl induced cellular transformation. See Ihle, J. N. "Janus kinases in cytokine signalling," *Philos Trans R Soc Lond B Biol Sci* 351:159-66, 1996; Leonard, W. J. "STATs and

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Clin Exp Immunol 108, 552-6, **1997**; Gurniak, C.B. and Berg, L.J. "Murine
JAK-3 is preferentially expressed in hematopoietic tissues and lymphocyte
precursor cells," *Blood* 87, 3151-60, **1996**; Rolling, C., Treton, D., Beckmann,

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receptor and is tyrosine phosphorylated following receptor triggering,"
Oncogene 10, 1757-61, **1995**; Rolling, C., Treton, D., Pellegrini, S., Galanaud,
P. and Richard, Y. "IL4 and IL13 receptors share the gamma c chain and activate
STAT6, STAT3 and STAT5 proteins in normal human B cells," *FEBS Lett* 393,

10 53-6, **1996**; Hanissian, S.H. and Geha, R.S. "JAK-3 is associated with CD40 and
is critical for CD40 induction of gene expression in B cells," *Immunity* 6,
379-87, **1997**; Danial, N.N., Pernis, A. and Rothman, P.B. "Jak-STAT signaling
induced by the v-abl oncogene," *Science* 269, 1875-7, **1995**.

15 **Summary**

Exposure of B-lineage lymphoid cells to ionizing radiation
induces an elevation of *c-jun* protooncogene mRNA levels. This signal is
abrogated by protein tyrosine kinase (PTK) inhibitors, indicating that activation
of an as yet unidentified PTK is mandatory for radiation-induced *c-jun*

20 expression. Experimental evidence shows that the cytoplasmic tyrosine kinases
BTK, SYK and LYN are not required for this signal. Lymphoma B-cells
rendered deficient for LYN, SYK or both by targeted gene disruption showed
increased *c-jun* expression levels after radiation exposure, but the magnitude of
the stimulation was lower than in wild-type cells. Thus, these PTK may

25 participate in the generation of an optimal signal. Notably, inhibitors of Janus
family kinase 3 (JAK-3) abrogated radiation-induced *c-jun* activation. This
suggests that JAKs are important regulators of radiation-induced *c-jun*
activation, and that JAK-3 inhibitors are useful for preventing or treating
diseases or conditions that result from chemical-induced or radiation-induced
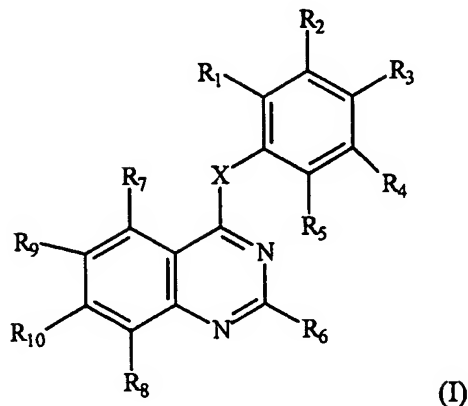
30 *c-jun* activation.

All publications, patents, and patent documents are incorporated
by reference herein, as though individually incorporated by reference. The
invention has been described with reference to various specific and preferred

embodiments and techniques. However, it should be understood that many variations and modifications may be made while remaining within the spirit and scope of the invention.

What is claimed is:

1.   A method comprising inhibiting c-jun activation in mammalian or avian cells by contacting the cells with a substance that inhibits the activity of Janus

5   family kinase 3 (JAK-3).

2.   The method of claim 1 wherein the c-jun activation results from exposure of the cells to ara-C, a topoisomerase II inhibitor, ultraviolet radiation, an alkylating agent, or ionizing radiation.

10

3.   The method of claim 1 wherein the c-jun activation results from exposure of the cells to ultraviolet radiation or ionizing radiation.

4.   The method of claim 1 wherein the contacting is performed *in vitro*.

15

5.   The method of claim 1 wherein the contacting is performed *in vitro*.

6.   The method of claim 2 wherein the contacting occurs prior to the exposure.

20

7.   The method of claim 2 wherein the contacting occurs after the exposure.

8.   The method of claim 1 wherein the substance is a protein.

9.   The method of claim 1 wherein the substance is a compound of formula

I:

(I)

wherein

5   X is HN, $R_{11}N$, S, O, CH_2, or $R_{11}CH$;

         R_{11} is hydrogen, (C_1-C_4)alkyl, or (C_1-C_4)alkanoyl;

         R_1-R_8 are each independently hydrogen, hydroxy, mercapto, amino, nitro,

(C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; wherein two adjacent

groups of R_1-R_5 together with the phenyl ring to which they are attached may

10   optionally form a fused ring, for example forming a naphthyl or a

tetrahydronaphthyl ring; and further wherein the ring formed by the two adjacent

groups of R_1-R_5 may optionally be substituted by 1, 2, 3, or 4 hydroxy, mercapto,

amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; and

         R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, (C_1-C_4)alkoxy,

15   halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a

pharmaceutically acceptable salt thereof.

10.   The method of claim 1 wherein the substance is 4-(4'-hydroxylphenyl)-

amino-6,7-dimethoxyquinazoline or 4-(3'-bromo-4'-hydroxylphenyl)-

20   amino-6,7-dimethoxyquinazoline; or a pharmaceutically acceptable salt thereof.

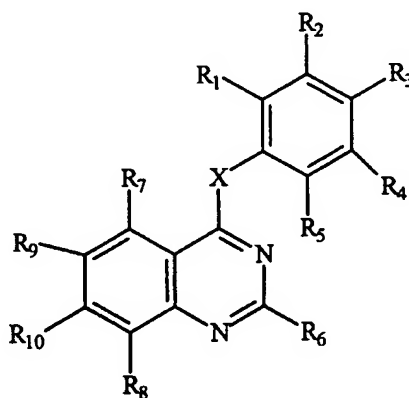11.   The method of claim 1 wherein the cells are mammalian.

12.   The method of claim 1 wherein the cells are human.

13.   The method of claim 1 wherein the cells are avian.

14.   A therapeutic method for preventing or treating a pathological condition
5   in a mammal wherein c-jun activation is implicated and inhibition of its
activation is desired comprising administering to a mammal in need of such
therapy, an effective amount of a substance that inhibits the activity of JAK-3.

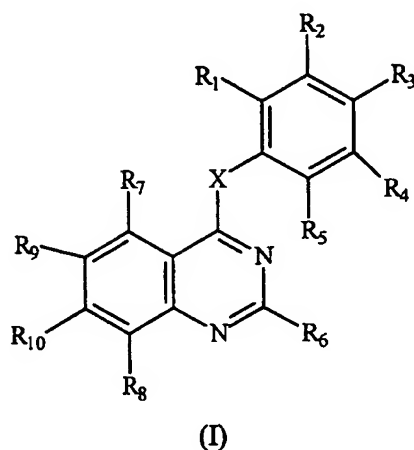15.   The use of a compound of formula I:

(I)

10   wherein
        X is HN, $R_{11}N$, S, O, CH_2, or $R_{11}CH$;

        R_{11} is hydrogen, (C_1-C_4)alkyl, or (C_1-C_4)alkanoyl;

        R_1-R_8 are each independently hydrogen, hydroxy, mercapto, amino, nitro,
(C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; wherein two adjacent
15   groups of R_1-R_5 together with the phenyl ring to which they are attached may
optionally form a fused ring, for example forming a naphthyl or a
tetrahydronaphthyl ring; and further wherein the ring formed by the two adjacent
groups of R_1-R_5 may optionally be substituted by 1, 2, 3, or 4 hydroxy, mercapto,
amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; and

20   R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, (C_1-C_4)alkoxy,
halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a
pharmaceutically acceptable salt thereof;

for the manufacture of a medicament for inhibiting the activity of Janus
family kinase 3 (JAK-3).

16.   The use of a compound of formula I:

(I)

5   wherein

X is HN, $R_{11}N$, S, O, CH_2, or $R_{11}CH$;

R_{11} is hydrogen, (C_1-C_4)alkyl, or (C_1-C_4)alkanoyl;

R_1-R_8 are each independently hydrogen, hydroxy, mercapto, amino, nitro,
(C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; wherein two adjacent

10   groups of R_1-R_5 together with the phenyl ring to which they are attached may
optionally form a fused ring, for example forming a naphthyl or a
tetrahydronaphthyl ring; and further wherein the ring formed by the two adjacent
groups of R_1-R_5 may optionally be substituted by 1, 2, 3, or 4 hydroxy, mercapto,
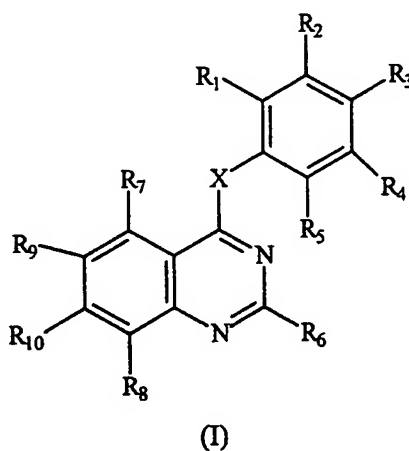amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; and

15   R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, (C_1-C_4)alkoxy,
halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a
pharmaceutically acceptable salt thereof; for the manufacture of a medicament
for inhibiting c-jun activation in mammalian or avian cells.

20   17.   The use of claim 16 wherein the c-jun activation results from exposure of
the cells to radiation or to chemical agents that cause DNA damage.

18.   The use of claim 16 wherein the c-jun activation results from exposure of

the cells to ara-C, a topoisomerase II inhibitor, ultraviolet radiation, an alkylating

agent, or ionizing radiation.

5   19.   The use of claim 16 wherein the c-jun activation results from exposure of

the cells to ultraviolet radiation or ionizing radiation.

20.   A compound of formula I:

(I)

wherein

10   X is HN, R_{11}N, S, O, CH_2, or R_{11}CH;

R_{11} is hydrogen, (C_1-C_4)alkyl, or (C_1-C_4)alkanoyl;

R_1-R_8 are each independently hydrogen, hydroxy, mercapto, amino, nitro,

(C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; wherein two adjacent

groups of R_1-R_5 together with the phenyl ring to which they are attached may

15   optionally form a fused ring, for example forming a naphthyl or a

tetrahydronaphthyl ring; and further wherein the ring formed by the two adjacent

groups of R_1-R_5 may optionally be substituted by 1, 2, 3, or 4 hydroxy, mercapto,

amino, nitro, (C_1-C_4)alkyl, (C_1-C_4)alkoxy, (C_1-C_4)alkylthio, or halo; and

R_9 and R_{10} are each independently hydrogen, (C_1-C_4)alkyl, (C_1-C_4)alkoxy,

20   halo, or (C_1-C_4)alkanoyl; or R_9 and R_{10} together are methylenedioxy; or a

pharmaceutically acceptable salt thereof; for use in medical therapy.

21. The compound of claim 20 wherein the therapy is preventing or treating a pathological condition in a mammal.

22. The compound of claim 21 wherein the pathological condition is tissue damage, organ damage, inflammation, hair loss, or the negative effects that are produced by oxygen free radicals during chemotherapy.

23. The compound of claim 22 wherein the organ is the heart, liver, or kidney.

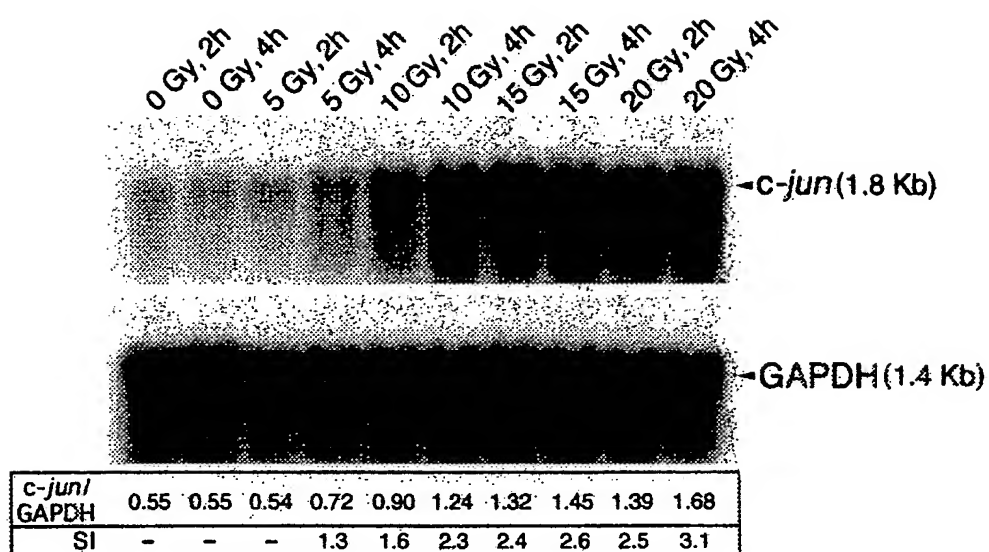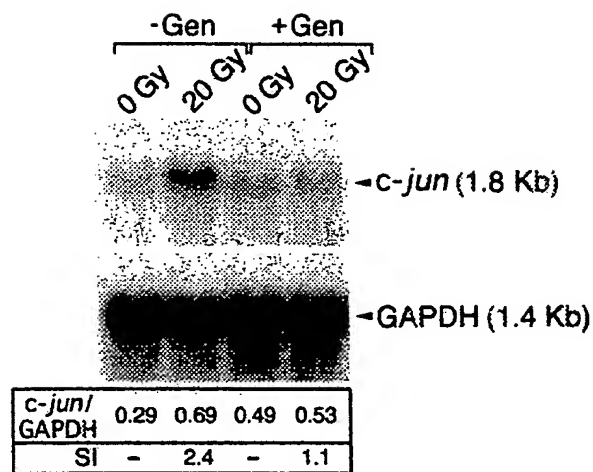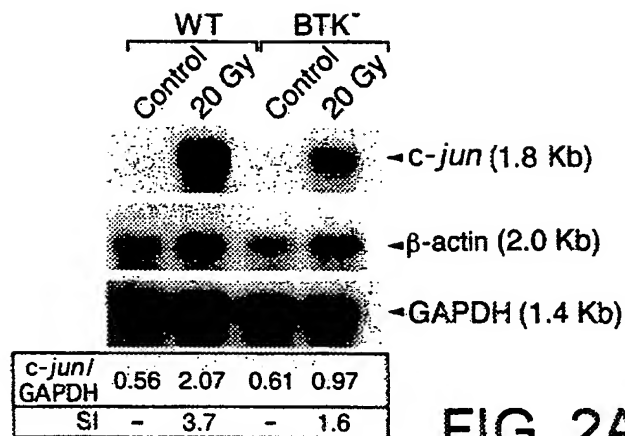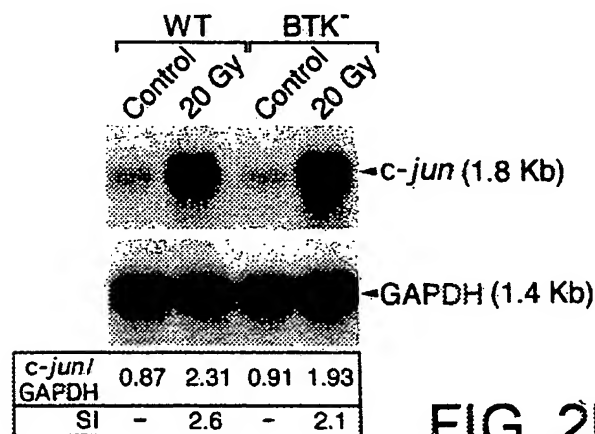| c-jun/ GAPDH	0.55	0.55	0.54	0.72	0.90	1.24	1.32	1.45	1.39	1.68
SI	–	–	–	1.3	1.6	2.3	2.4	2.6	2.5	3.1

FIG. 1A

FIG. 1B

FIG. 2A

FIG. 2B

	WT		BTK⁻		SYK⁻	
	Control	20 Gy	Control	20 Gy	Control	20 Gy
c-jun/GAPDH	0.41	1.50	0.35	1.37	0.57	1.38
SI	–	3.6	–	3.9	–	2.4

c-jun (1.8 Kb)
β actin (2.0 Kb)
GAPDH (1.4 Kb)

FIG. 3A

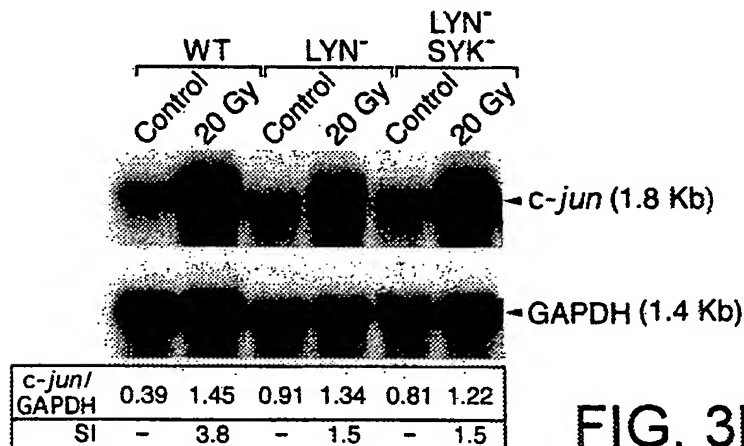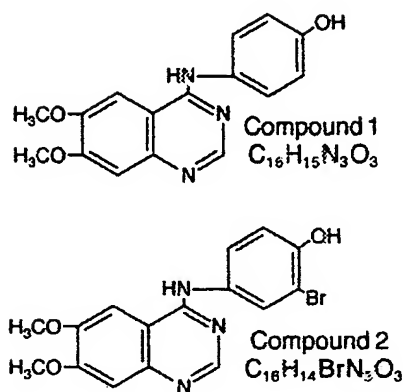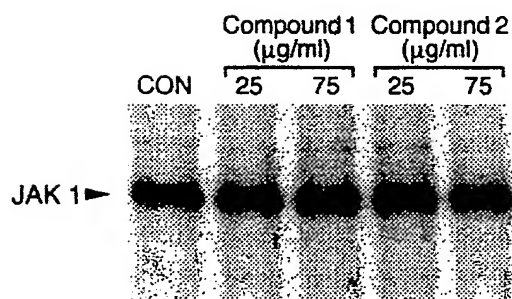|	WT		LYN⁻		LYN⁻ SYK⁻	
	Control	20 Gy	Control	20 Gy	Control	20 Gy
c-jun/GAPDH	0.39	1.45	0.91	1.34	0.81	1.22
SI	–	3.8	–	1.5	–	1.5

c-jun (1.8 Kb)
GAPDH (1.4 Kb)

FIG. 3B

FIG. 4A

FIG. 4B-1

FIG. 4B-2

FIG. 4B-3   FIG. 4B-4

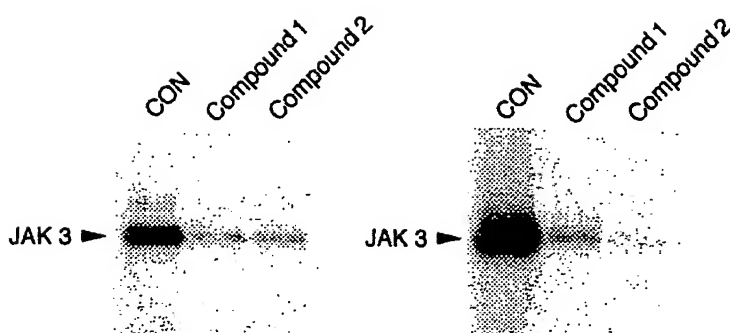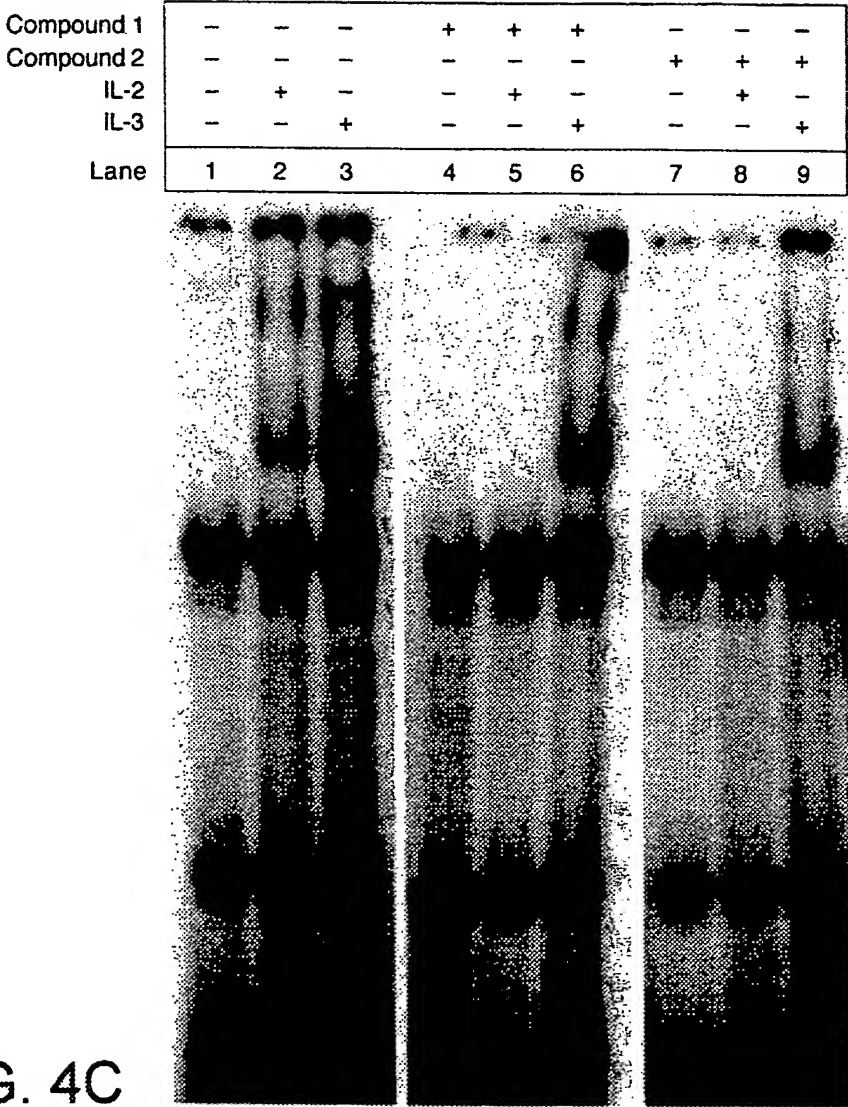| Compound 1	–	–	–	+	+	+	–	–	–
Compound 2	–	–	–	–	–	–	+	+	+
IL-2	–	+	–	–	+	–	–	+	–
IL-3	–	–	+	–	–	+	–	–	+
Lane	1	2	3	4	5	6	7	8	9

FIG. 4C
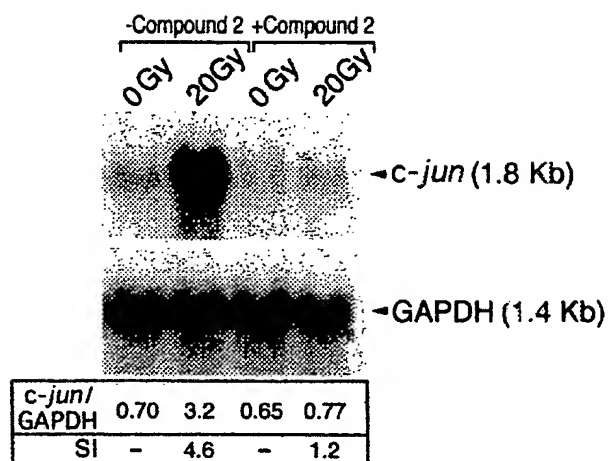
FIG. 5

1

SEQUENCE LISTING

<110> Hughes Institute, et al.

<120> Method for inhibiting c-jun expression
      using JAK-3 inhibitors.

<130> 957.001WO1

<150> US 60/091150
<151> 1998-06-30

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   A61K31/517   C07D243/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   A61K   C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	R K NARLA ET AL: "4-(3'-BROMO-4'HYDROXYPHENYL)AMINO-6,7-DIM ETHOXYQUINAZOLINE:" CLINICAL CANCER RESEARCH,US,THE AMERICAN ASSOCIATION FOR CANCER RESEARCH, vol. 4, no. 6, page 1405-1414-1414 XP002113201 ISSN: 1078-0432 abstract	20-23
Y	the whole document table 1	1-19
X	WO 95 03701 A (ST JUDE CHILDRENS RES HOSPITAL) 9 February 1995 (1995-02-09) claims 1,4,6,8,10 . page 37, line 1-8	1,4,7,8, 11-14
	-/--	

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 November 1999	29/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Uiber, P

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 03358 A (US HEALTH ;LEONARD WARREN J (US)) 30 January 1997 (1997-01-30) example 16 claims 1-9 ---	1-19
P,X	GOODMAN, PATRICIA A. ET AL: "Role of tyrosine kinases in induction of the c-jun proto-oncogene in irradiated B-lineage lymphoid cells" J. BIOL. CHEM., 1998, 273, 17742-17748, XP002122432 abstract page 17747, column 1, paragraph 3 -column 2, paragraph 1 -----	1-23

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9503701	A	09-02-1995	AU	5265493 A	09-02-1995
			AU	7518294 A	28-02-1995
			CA	2126523 A	30-01-1995
			CA	2168098 A	09-02-1995
			EP	0712277 A	22-05-1996
			JP	7107983 A	25-04-1995
			JP	9503384 T	08-04-1997
			US	5955290 A	21-09-1999
WO 9703358	A	30-01-1997	AU	6407696 A	10-02-1997